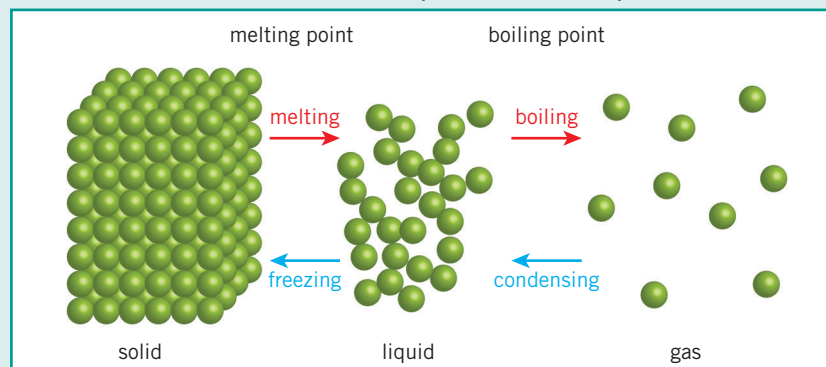


# Chapter 3: Bonding 1

## Knowledge organiser

### Particle model

The three states of matter can be represented in the particle model.



(HT only) This model assumes that:

- there are no forces between the particles
- that all particles in a substance are spherical
- that the spheres are solid.

The amount of energy needed to change the state of a substance depends on the forces between the particles. The stronger the forces between the particles, the higher the melting or boiling point of the substance.

### Covalent bonding

Atoms can share or transfer electrons to form strong chemical bonds.

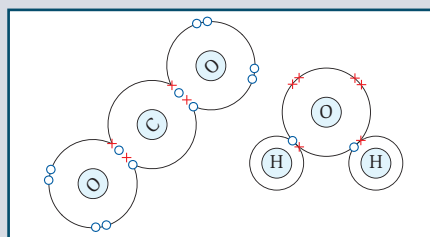
A **covalent bond** is when electrons are *shared* between **non-metal** atoms.

The number of electrons shared depends on how many extra electrons an atom needs to make a full outer shell.

If you include electrons that are shared between atoms, each atom has a full outer shell.

**Single bond** = each atom shares one pair of electrons.

**Double bond** = each atom shares two pairs of electrons.



### Covalent structures

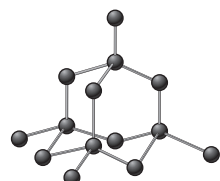
There are three main types of covalent structure:

Structure and bonding

#### Giant covalent

Many billions of atoms, each one with a strong covalent bond to a number of others.

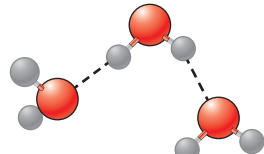
An example of a giant covalent structure is diamond.



#### Small molecules

Each molecule contains only a few atoms with strong covalent bonds between these atoms. Different molecules are held together by weak **intermolecular forces**.

For example, water is made of small molecules.



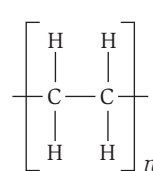
#### Large molecules

Many repeating units joined by covalent bonds to form a chain.

The small section is bonded to many identical sections to the left and right. The 'n' represents a large number.

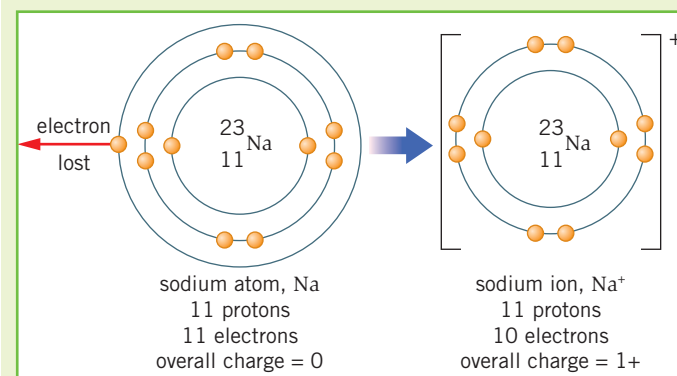
Separate chains are held together by intermolecular forces that are stronger than in small molecules.

Polymers are examples of long molecules.



### Ions

Atoms can gain or lose electrons to give them a full outer shell. The number of protons is then different from the number of electrons. The resulting particle has a charge and is called an **ion**.



### Conductivity

Solid ionic substances do not conduct electricity because the ions are fixed in position and not free to carry charge.

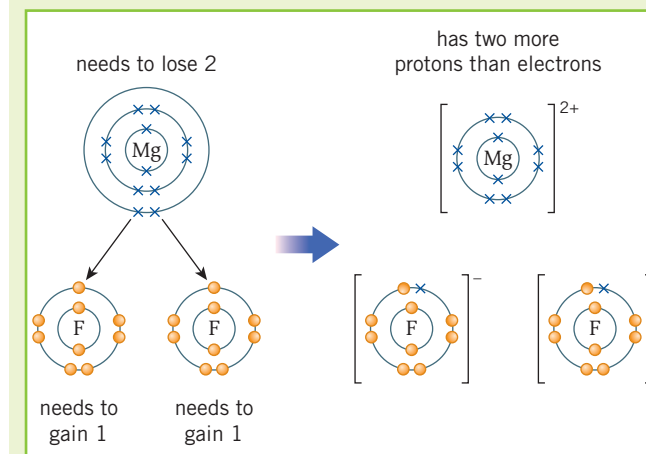
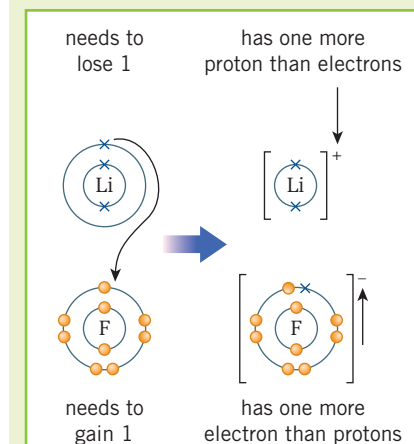
When melted or dissolved in water, ionic substances do conduct electricity because the ions are free to move and carry charge.

### Melting points

Ionic substances have high melting points because the electrostatic force of attraction between oppositely charged ions is strong and so requires lots of energy to break.

### Ionic bonding

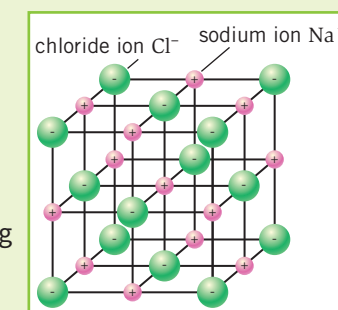
When metal atoms react with non-metal atoms they **transfer** electrons to the non-metal atom.



Metal atoms lose electrons to become positive ions. Non-metal atoms gain electrons to become negative ions.

### Giant ionic lattice

When metal atoms transfer electrons to non-metal atoms you end up with positive and negative ions. These are attracted to each other by the strong **electrostatic force of attraction**. This is called ionic bonding.

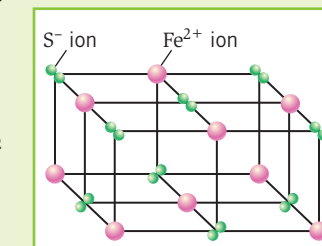


The electrostatic force of attraction works in all directions, so many billions of ions can be bonded together in a 3D structure.

### Formulae

The formula of an ionic substance can be worked out

- 1 from its bonding diagram:  
for every one magnesium ion there are two fluoride ions – so the formula for magnesium fluoride is  $\text{MgF}_2$
- 2 from a lattice diagram:  
there are nine  $\text{Fe}^{2+}$  ions and 18  $\text{S}^{2-}$  ions – simplifying this ratio gives a formula of  $\text{FeS}_2$



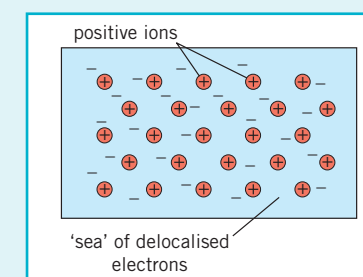
### Metals: structure and properties

The atoms that make up metals form layers. The electrons in the outer shells of the atoms are **delocalised** – this means they are free to move through the whole structure.

The positive metal ions are then attracted to these delocalised electrons by the electrostatic force of attraction.

Some important properties of metals are:

- pure metals are **malleable** because the layers can slide over each other
- they are good **conductors** of electricity and of thermal energy because delocalised electrons are free to move through the whole structure
- they have high melting and boiling points because the electrostatic force of attraction between metal ions and delocalised electrons is strong so lots of energy is needed to break it.



# Chapter 3: Bonding 2

## Knowledge organiser

### Properties

High melting and boiling points because the strong covalent bonds between the atoms must be broken to melt or boil the substances.  
This requires a lot of energy.  
Solid at room temperature.

Low melting and boiling points because only the intermolecular forces need to be overcome to melt or boil the substances, not the bonds between the atoms.  
This does not require a lot of energy as the intermolecular forces are weak.  
Normally gaseous or liquid at room temperature.

Melting and boiling points are low compared to giant covalent substances but higher than for small molecules.  
Large molecules have stronger intermolecular forces than small molecules, which require more energy to overcome.  
Normally solid at room temperature.

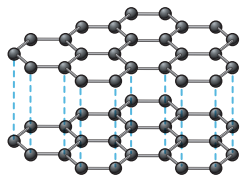
Most covalent structures do not conduct electricity because they do not have **delocalised electrons** or ions that are free to move to carry charge.

### Graphite

Graphite is a giant covalent structure, but is different to other giant covalent substances.

#### Structure

Made only of carbon – each carbon atom bonds to three others, and forms hexagonal rings in layers. Each carbon atom has one spare electron, which is delocalised and therefore free to move around the structure.



#### Hardness

The layers can slide over each other because they are not covalently bonded. Graphite is therefore softer than diamond, even though both are made only of carbon, as each atom in diamond has four strong covalent bonds.

#### Conductivity

The delocalised electrons are free to move through graphite, so can carry charges and allow an electrical current to flow. Graphite is therefore a conductor of electricity.

### Graphene

Graphene consists of only a single layer of graphite. Its strong covalent bonds make it a strong material that can also conduct electricity. It could be used in composites and high-tech electronics.

### Fullerenes

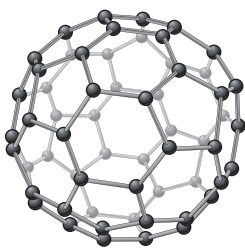
- hollow cages of carbon atoms bonded together in one molecule
- can be arranged as a sphere or a tube (called a **nanotube**)
- molecules held together by weak intermolecular forces, so can slide over each other
- conduct electricity

#### Spheres

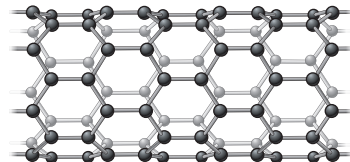
Buckminsterfullerene was the first fullerene to be discovered, and has 60 carbon atoms.

Other fullerenes exist with different numbers of carbon atoms arranged in rings that form hollow shapes.

Fullerenes like this can be used as lubricants and in drug delivery.



#### Nanotubes

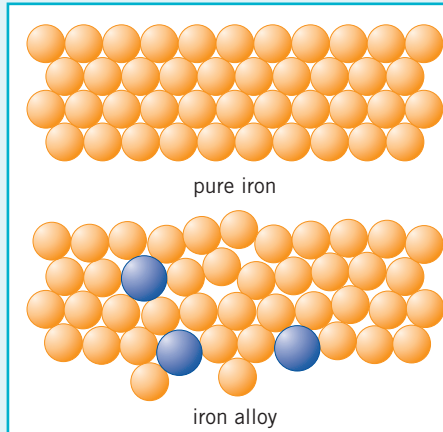


The carbon atoms in nanotubes are arranged in cylindrical tubes.

Their high **tensile strength** (they are difficult to break when pulled) makes them useful in electronics.

### Alloys

Pure metals are often too soft to use as they are. Adding atoms of a different element can make the resulting mixture harder because the new atoms will be a different size to the pure metal's atoms. This will disturb the regular arrangement of the layers, preventing them from sliding over each other.  
The harder mixture is called an **alloy**.



### Measuring particles

We use different units and scales to measure the size of particles.

Particle	Particulate matter	Size	Standard form	Full form
grain of sand	N/A	0.1 mm	$1 \times 10^{-4}$ m	0.0001 m
coarse particles (e.g., dust)	PM <sub>10</sub>	10 $\mu$ m	$1 \times 10^{-5}$ m	0.00001 m
fine particles	PM <sub>2.5</sub>	100 nm	$1 \times 10^{-7}$ m	0.0000001 m
nanoparticles	< PM <sub>2.5</sub>	1 to 100 nm	$1 \times 10^{-9}$ to $1 \times 10^{-7}$ m	0.000000001 m to 0.0000001 m

PM stands for **particulate matter** and is another way of measuring very small particles.

### Uses of nanoparticles

Nanoparticles often have very different properties to bulk materials of the same substance, caused by their high surface area-to-volume-ratio.

Nanoparticles have many uses and are an important area of research. They are used in healthcare, electronics, cosmetics, and as catalysts.

However, nanoparticles have the potential to be hazardous to health and to ecosystems, so it is important that they are researched further.

### Key terms

Make sure you can write a definition for these key terms.

conductivity    conductor    delocalised electron    electrostatic force of attraction  
ion    lattice    layer    malleable    nanoparticle    particulate matter  
surface area to volume ratio    transfer